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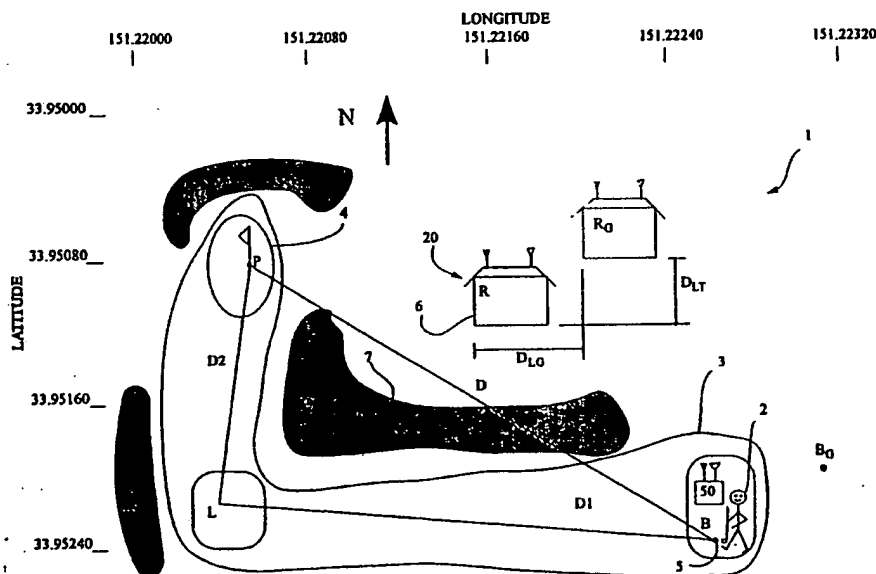
(57) Abstract

A distance measuring system is disclosed in which a user (2) in possession of a portable distance calculator (50) can determine the distance (D1, D) between an actual position (B) and a fixed position (L, P). Satellite position data of the fixed position (L, P) is determined periodically and supplied to the calculator (50). The calculator (50) includes a satellite position receiver (51) and a processor (54) which permit the distance (D1, D) to be determined. In a preferred embodiment error correction is performed by determining a satellite differential position error at a known survey reference location (R) and supplying the error to the calculator (50) for correction of the actual position (B) and, where necessary, the fixed position (L, P).

A DISTANCE MEASURING SYSTEM

FIELD OF THE INVENTION

The present invention relates to distance measurement and, in particular, discloses a method and appears which is used to determine the distance between a variable position and one or more of a number of fixed positions.

BACKGROUND ART

In many fields of endeavour, such as surveying and navigation to name but two, it is necessary to determine distances, preferably quickly, accurately and economically. Hitherto, line of sight distances have been determined using lasers and other optical apparatus which, whilst providing a highly accurate result, are often expensive and cumbersome to use.

One particular example of where known optical devices are poorly adapted for use is where, during the course of a game of golf, it is necessary to determine the distance between the golf ball and the pin position (the "hole"). This is required so that the golf player can choose an appropriate club with which the ball can be struck. It is important that the distance be determined with some level of accuracy in view of the different distances afforded by different clubs.

Typically, a golfer can estimate the distance using his best judgement. This "traditional" method is that internationally accepted by the sport at competition levels, but at non-competitive levels, some players prefer a more accurate method by which their game can be improved. Generally, an accuracy better than 10 metres is required ¬s this, for example, can be the difference in range between a 7 and 8 iron. It is common practice to pace out the distance from the golf ball to the pin on a golf course. This met. od is very time consuming and frustrating for all players, as it slows down the throughput of the number of players on the course at one time.

It is an object of the present invention to substantially overcome, or ameliorate, the problems associated with the prior art through provision of a distance measuring system which permits the taking of
5   distance measurements relatively accurately and conveniently.

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention there is disclosed a method for determining the distance
10   between a variable position and one or more of a plurality of fixed positions, said method comprising the steps of obtaining first satellite position information of one of said fixed positions and supplying said first information to a user for use at said variable position, said user
15   obtaining second satellite position information of said variable position, and subsequently calculating the distance between said variable position and said fixed position using said first position information and said second position information.
20   Preferably, the method also includes the step of obtaining third satellite position information of a reference location and comparing same with survey position information of said reference location to determine a satellite position information differential error, said
25   error being supplied to said user to permit correction of errors in said first and second position information, prior to calculating said distance.

In accordance with another aspect of the present invention there is disclosed a distance measuring system
30   comprising a base station having a control means and a data transmitter means, said control means being configurable with first satellite position information obtained from a (first) portable satellite position receiver, of one or more fixed positions, said first position information being
35   communicable by said data transmitter means to one or more

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portable distance calculators, each said distance calculator
comprising a (second) satellite position information
receiver, a data receiver means means adapted to receive
data from said data transmitter means, and a processor
5   means, said processor means accepting said first satellite
position information of a fixed position selected by a user
of said calculator and actual position information provided
by said second satellite position receiver, and subsequently
calculating the distance therebetween and presenting said
10   distance for consideration by said user.

        Preferably, the system further includes a third
satellite position information receiver arranged at a
reference location and configured to periodically provide
satellite position information of said reference location
15   whereby said control means compares a pre-determined survey
position of said reference location with said satellite
position of said reference location to determine a satellite
position information error, said error being supplied to
said portable distance calculator(s) for correction of said
20   satellite position information used by said calculators.

        Generally, the fixed positions can be golf pin locations
and the variable position that of the golf ball, for
example.

        BRIEF DESCRIPTION OF THE DRAWINGS
25   A number of preferred embodiments of the present
invention will now be described with reference to the
drawings in which:

        Fig. 1 schematically illustrates one hole of a golf
course configured with the preferred embodiments;
30   Fig. 2 is a schematic block diagram representation of
one embodiment of the base station of Fig. 1;

        Fig. 3 is a schematic block diagram representation of
one embodiment of the portable distance calculator of Fig.
1;

35

Fig. 4 is a schematic block diagram representation of another embodiment of the portable distance calculator of Fig. 1;

Figs. 5 and 6 illustrate various attributes and errors associated with the GPS satellite system;

Fig. 7 is a schematic block diagram representation of another embodiment of the base station of Fig. 1; and

Appendix 1 shows a pseudo-code computer program used to implement the preferred embodiment; and

Appendix 2 is an illustrative example of distance calculation.

BEST AND OTHER MODES FOR CARRYING OUT THE INVENTION

As seen in Fig. 1, a golf course 1 is shown in which a golf player 2 is situated on a fairway 3 and about to "tee off" so as to approach a green 4. The green 4 includes a pin position P which is seen to be at a lineal distance D from a position B of a golf ball 5. Because of the existence of an obstruction 7 (trees, for example), the fairway 3 "dog-legs" at a position L which gives the actual distance to the green 4 being the sum of two distances D1 and D2, as illustrated. The position L marks an area at which the golfer's first stroke is intended to land and for which the distance D1 must be determined.

The golfer 2 is able to calculate the distance D1 using a portable distance calculator 50 which is operated at the location B. The portable distance calculator 50 receives position information from navigational satellites orbiting the earth, as well as data received from a base station 20, which can be arranged at a club house 6. The base station 20 resides at a reference position R whose position on Earth is accurately known from survey data that is obtained by usual survey methods, and which are quite accurate.

There have recently become available satellite position receivers which can provide position information in latitude, longitude and elevation using navigational

satellite systems, such as the Global Positioning System
(GPS) satellite network. GPS receivers are well known in
the art and are typically used for navigation on land and at
sea.

5   Referring now to Fig. 2, the base station 20 includes a
GPS receiver 21 configured at the known reference location
R. The GPS receiver 21 supplies GPS position information of
the reference location R to a control unit 23. An input
buffer 24 of the control unit 23 provides interconnection

10   between the GPS receiver 21 and a controlling processor 26.
The control unit 23 also includes a memory unit 29 having
a number of memory locations dedicated for specific blocks
of data used in the system. The control unit 23 is
configured firstly to obtain the GPS position of the

15   reference location R by means of position information output
from the GPS receiver 21 and record same in a predetermined
memory location 30. The GPS position in the memory location
30 is continually updated and so can vary according to the
error in the satellite system at that latitude, longitude

20   and altitude, at that particular time of day. The memory
unit 29 is additionally pre-programmed with the actual
s...vey position of the reference location R which is stored
in a memory location 33.

        Using the survey position 33, and the continually
25   updated GPS position 30, the processor 26 can calculate, and
continually update, a GPS differential error 31 indicative
of the actual error in the position information received ·
from the GPS receiver 21.

        Returning to Fig. 1, a ghost position R_G of the reference
30   location R is shown which represents the GPS position in the
memory location 30 provided by the GPS receiver 21. In the
example illustrated:

$$R = 33.95080°S , 151.22160°E , \text{and}$$
$$R_G = 33.95040°S , 151.22200°E.$$

35   This value gives a differential latitude error

$$D_{LT} = -0.00040°,$$

and a differential longitude error of

$$D_{LG} = +0.00030°.$$

These values together form a GPS differential error

5 which is calculated by the processor 26 and stored in a

memory location 31.

The control unit 23 is also provided with a input

keyboard 27 and a display 28, through which a user can input

satellite recorded values of the pin position P and the

10 position L. This information can be programmed into the

control unit 23 in several ways. One alternative is a

hardware data link, from a hand held data logger including

an integral GPS receiver (ie: one of the portable

calculators 50), that would be used to obtain the pin

15 position P, and any "dog leg" positions L.

At most golf courses, the actual location on the green

of each pin is changed from time to time as determined by the

green keeper. Where this occurs, it is necessary for the

pin positions 32 recorded in the control unit 23, be updated

20 contemporaneously so that the system can operate accurately.

This update can be performed once each pin is repositioned

with the new positional data being entered into the control

unit 23 and subsequently the calculator 50 prior to the

commencement of play.

25 The base station 20 is configured, using a radio data

transmitter 22 to broadcast/transmit data around the golf

course indicative of the position of each of the pins and

any "dog legs". The GPS differential error 31 is also

transmitted so that positional data errors about the golf

30 course can be corrected (to be described). The radio data

transmitter 22 can be configured to operate on any useful

frequency, such as 173 MHz, and can use any method of

modulation suitable for transmitting data, such as frequency

modulation (FM).

35

Turning now to Fig. 3, the portable distance calculator
50 includes a radio data receiver 52 adapted to receive
signals transmitted from the transmitter 22. Data received
by the receiver 52 is supplied to a controlling processor 54
5   via an input buffer 53. The data received is stored in a
memory unit 57 that comprises locations for a product code
58, a personal identification code (PIC) 59, offset error
data 60, pin position data 61, and the GPS differential
error 62. The portable distance calculator 50 also includes
10   its own GPS receiver 51 which allows the determination of
the GPS position of the current position of the ball 5. In
Fig. 1, the GPS position of the ball 5 is the ghost position
B_G, in a corresponding manner to the GPS position of
reference location R being R_G. The GPS position B_G of the
15   ball 5 is stored in a memory location 63 in the memory unit
57. In this configuration, the distance calculator 50 can,
using a selected pin position 61 (e.g. pin 2 dogleg) and the
GPS position B_G of the ball 5, determine the distance D1
between the position B of the ball 5 and the position of the
20   dog leg L. The same procedure can be repeated for each
stroke required to reach the golf pin P.
The distances are calculated using trigonometry, and
also taking into account the change of longitude grid
distances away from the equator. This corrects for the
25   earth's non-spherical shape. The longitude/latitudes are
then converted into metres or yards as some players prefer.
It is necessary to correct for the earths curvature to
obtain accurate results. Similarly it is necessary to
convert the navigation units into metres (or yards) to give
30   purpose to the distances calculated. The pseudo-code of
Appendix 1 shows a simplified version of performing such
calculations and Figs. 5 and 6 and the following give a
worked example. The diagram of the Earth in Fig. 6., shows
that the longitude lines vary in distance apart from zero at
35   the poles to maximum at the equator. The relationship for

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this is a Cosine function of the latitude, zero degrees
being the equator and 90 degrees being the poles.

$$COS(0\ deg)=1 \qquad COS(90\ deg)=0$$

5   It is known that the earth is not uniformly circular
upon its axis, and in highly accurate navigational
situations this would need to be taken into account.
However, in the preferred embodiment distances are measured
across only relatively short distances, and accordingly any
differences encountered are irrelevant. Hence, the use of
10 the WGS-84, World DATUM for the equatorial radius. WGS-84
states the radius at the equator is 6378.137 km. Converting
this into metres at the resolution used by the system
(0.00001deg).

    Longitude metres per 0.00001 degree at the equator.

15     $Lgeq = ((2*PI*6378137)/360)*0.00001=1.11319$ metres.

    The Polar radius is equal to 6357.000km.

    Latitude metres per 0.00001 degree.

    $Lt=((2*PI*6357000)/360)*0.00001=1.10951$ metres.

20

    Appendix 2 gives an example of distance calculation
based on the above principles.

    These are the smallest units used by the system and
provide a 2-5 metre accuracy (for 50% of readings) for the
25 system, as a whole.

    Bearing calculations are used in determining the
direction that the ball was hit, and for the statistical
purpose of calculating the distance the ball was "Hooked" or
"Sliced" away from the 'ideal' centre of the fairway.

30   On 25th March 1990, the United States Department of
Defence, who operates the GPS satellites, formally
implemented Selective Availability (SA). Selective
Availability is a method of denying unauthorized,
nonmilitary, GPS users high position accuracy with coarse
35 acquisition code (C/A code). The reason behind this is so

that they are not supplying the "enemy" with such a useful
tool, which could be used against them. However the
Department of Defence has stated that the policy of
Selective Availability would be reviewed annually in an
5   effort to increase the accuracy available as conditions
warrant.

The GPS has a number of errors which need be considered
in various applications.   Those errors are:

1. Satellite Ephemeris prediction errors;

10   2. Satellite clock prediction errors;

3. Ionospheric delay errors;

4. Tropospheric delay errors as they appear at the
reference station;

5. Artificial errors induced by Selective

15   Availability (SA) techniques;

6. Differential tropospheric delay error, if
desired; and

7. Reference station clock offsets.

The first five of these errors are common to both the

20   user 2 and the base station 20, although this commonality is
to be reduced (except for clock prediction errors and
certain SA errors) as the distance between the user 2 and
the base station 20 increases. The last two are provided by
the reference station in order for the user to correct for

25   errors that are not in common; the last one only affects the
user's ability to determine absolute time.

Accordingly, the differential error message output from
the base station 20 provides as its primary correction a
number pseudorange corrections. The correction message

30   output from the base station 20 contains data for all the
satellites in view of the base (reference) station 20. The
pseudorange correction is a predicted correction. It will
diverge from the proper correction as it "grows old".
Because of this characteristic, the pseudorange correction

35   is preferably updated and transmitted as often as possible.

The user equipment preferably updates the corrections accordingly.

A range rate correction is also provided and is designed to compensate for the predicted rate of change of the pseudorange correction. This is an attempt to "extend the life" of the pseudorange correction as it "grows old".

In the illustration of Fig. 1, the GPS receiver 51, in attempting to determine the position B, as stated earlier actually provides the ghost position B_G.

Fig.5 shows a representation of the GPS orbiting satellites or space vechicles (SV's), the ionosphere, the reference station and the user. Also shown is a differential zone that can have a radius in the order 100's kilometres or more. Due to the fact that the satellites SV orbit the earth at altitudes of 20,183 km. Pythagoras theorem can be used to determine the angle theta subtended between the user and the reference location. It is apparent that the ratio of a few hundred kilometres to 20,183 km is huge, and for this reason, the GPS specification states that the differential error at any one time is constant for a radius of about 100 km about the location at which the position is measured. Therefore, GPS error 31 obtained at the survey location R is indicative of the error around the entire golf course.

Accordingly, the GPS error 62, comprising D_{LT} and D_{LG}, can be used to correct the ghost position B_G to give the actual position B. This is obtained by subtracting the differential error from the measured position. Accordingly, for Fig. 1:

$$B = B_G - (D_{LT}, D_{LG})$$
$$= (33.95200, 151.22310) - (-0.00040, 0.00030).$$

Giving $B = 33.95240°S , 151.22280°E$

The positional data of P and L can be corrected in a similar manner to give

$$P = 33.95080°S, 151,22060°E; \text{ and}$$

L = 33.95190°S, 151.22030°E.

Using the positions B and L, the first distance D1 can
be calculated trigonometrically where the latitude
difference is 0.00050° and the longitude difference is
5   0°00250.

Using the latitude and longitude corrections indicated
above, the distance D1 can be calculated as follows:

$$D1 = \sqrt{((50 \times 1.10951)^2 + (250 \times 1.11319)^2)}$$

10   = 278.3 metres.

The distance D2 is calculated once the ball 5 has landed
near the dog-leg.

Because a golf course is small, in a global sense,
the GPS error 31 obtained at the survey location R, is
15   indicative of the error around the entire golf course.

Because the golf course is basically a grid on which
each of the pins are mapped, any other location can also be
stored that can be useful to the player. If the fairway had
a dog leg approach to the pin, the ideal dog leg position can
20   also be mapped, so that the distance and bearing to the
ideal dog leg can be displayed.

Furthermore, it is possible to log any new position and
actually calculate the distance at which the last "shot" was
hit. This can also be useful for determining an average
25   distance hit for each club, for example.

It is envisaged that the distance calculators 50 are
hired either from the golf club or used with the permission
of the golf club, having paid some form of user licence. For
example, on entering the golf course, the golf player 2 can
30   pay an additional fee for the use of a portable distance
calculator 50. Alternatively, if the player 2 has his own
calculator 50, an alternative fee can be provided. Upon
payment of the fee, the golf player can be provided with a
daily personal identification code (PIC) 59 with which the
35   player 2 must enter into the keypad 55 so as to enable use of

the data received from the base station 20. The personal
identification code entered into the keypad 55 is checked
against that received and stored in memory location 59 and
if both coincide, the calculation of the distance is

5   permitted. The product code 58 permits use of distance
calculators 50 on the golf course 1 where the base station
20 has a corresponding or complementary code. This prevents
unlicensed or unauthorized use.

In use, the system shown in Figs. 1 to 3 must permit

10   operation over long periods of time. In this manner, the
data transmitter 22 being arranged at a club house or other
like location, is configured to transmit continually, so
that golf players are not inconvenienced when taking
distance measurements. To undertake a distance measurement,

15   the golf player 2 stands over the golf ball 5 and enters the
daily personal identification code 59 once at switch on into
the keypad 55. The entry of the code wakes the distance
calculator 50 from a quiescent, battery power saving state
and energizes the GPS receiver 51 and the data receiver 52.

20   When the data receiver 52 detects data transmitted from the
transmitter 22, the PIC 59 is initially checked, and if they
correspond, the remaining pin position data 61 and GPS error
are loaded into the memory 57. When both the pin position 61
and the GPS position 63 are stored in memory 57, the

25   processor 54 indicates, using the display 56 that positional
data is available and the golf player need then only enter
the particular pin position required. For example, if the
golf player is on a hole, pin position 9 is entered. The
processor 54 then selects the position of pin 9 and the

30   present GPS position 63, corrects each of those positions
using the GPS error 62, and then calculates the distance D
between those two positions which is displayed on the
display 56. The golf player 2 can then select an
appropriate club so as to best cover the distance D.

35

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The preferred embodiment described above can provide a distance measuring accuracy of about 2 to 5 metres or better using both averaging of the GPS receive data and calculation of the differential error.

5   Fig. 4 shows a specific architecture of a portable distance calculator 100, complementing the schematic of Fig. 3, and has a microcontroller 101 which includes a boot EPROM programmed with the pseudo-code of Appendix 1.

A line driver/receiver 102 permits interconnection
10   between the microcontroller 101 and a personal computer thereby permitting direct programming of the pin positions prior to the commencement of play, in which case the personal computer can be configured as the control unit 23. The pin positions are stored in memory comprising Flash RAM
15   103, such as a memory card, and static RAM 104.

User interface is provided by a keypad matrix 105 having an associated keypad decoder 106, and an LCD display 107, driven via a LCD controller 108 having a dedicated LCD SRAM 109.

20   The calculator 100 is powered by a battery power supply 110 which outputs two voltages V1 and V2, nominally +5V and +1.5V, respectively.

The V1 supply powers all digital circuitry within the calculator 100. The V2 supply is input into a data link
25   antenna and receiver 111. The line driver/receiver 102 also includes a voltage inverter which creates further supplies V3 and V4 (nominally +10V and -10V respectively). V3 and V4 supply a low noise preamplifier 112 which buffers signals output from the receiver 111 to a modem 113.

30   GPS signals are detected by a FOG antenna and amplifier 114 which outputs to a GPS receiver 115 which demodulates the received signal to output GPS position data.

The modem 113 and GPS receiver 115 each transmit and receive data to/from the microcontroller via a dual
35   universal asynchronous receiver/transmitter (DUART) 116.

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Crystals 117 and 188 provide clock signals for the
transmission of data to/from and about the calculator 50.

Fig. 7 shows an alternative arrangement of a base
station 150 which is configured with a differential GPS

5   reference station 151. The station 151 can be a Trimble
Reference Locator II recently manufactured by Trimble
Navigation of Sunnyvale, California, U.S.A. The reference
station 151 is autonomous device arranged to calculate and
transmit differential corrections to mobile GPS receivers.

10   That station 151 has a nine channel architecture which
enables it to track and generate precise differential
corrections for all GPS satellites in view at any one time.
Accordingly, a possible nine different error readings can be
transmitted which enables the calculator to select the error

15   corresponding to the satellite from which it receives
positional data. Alternatively, an average of the nine
errors can be transmitted. The differential corrections are
output on an RTCM SC-104 standard format data link to a
modem 152 which transfers same to an FM transmitter 153 for

20   broadcasting to the portable calculators 50,100. The GPS
receiver 115, when taking positional measurements, obtains
data from a number (up to 6) of the GPS satellites and each
group of satellite data can then be corrected with
corresponding error data obtained via the reference station

25   151. from the corrected individual satellite data, the
actual position is calculated.

It will be apparent from the foregoing that a golf
player can readily obtain distance information between any
location.on the golf course, and.any particular pin hole.

30   For example, the distance calculator 50 can also be used
as a personal data base with which a golfer can calculate
and compare one's own performance over a particular
course. For example, the calculator 50 can be .readily
adapted to calculate the successive distance to the hole,

35   for example, over a par 5 hole. Additionally, the

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calculator 50 can be pre-programmed with average distance
hits for a particular golfer with specific clubs. In this
manner, depending on the distance calculated, the calculator
50 can be used to recommend a particular club suiting the

5   next particular shot to be played. A further modification
is to correct for errors in altitude and hence provide more
accurate distance measurement over hilly golf courses. It
is also possible to incorporate directional bearing
information to enable the golfer to determine the direction

10   of the pin relative to his stance, whether or not the pin is
visible to the golfer.

    Furthermore, because the device 50 is a calculator of
sorts, in that it has a keypad and display, it is possible to
incorporate into the device an electronic score pad for use

15   during the game, keeping and adding scores as required.
Also the LCD display 107, because it is a 2-dimensional
pixel array, can be configured as a graphical display with
map capabilities for a graphical display of each fairway.
Any map data can be supplied directly to the calculator 100

20   with the pin and dogleg positions via the personal computer
connection and into the SRAM 104, or via a memory card
operating as the Flash RAM 103.

    It will be apparent that the system disclosed herein is
not only applicable to short range, line-of-sight distance

25   measurement such as in go.., but can be used in a variety of
arts, including bushwalking, for example. Furthermore, the
system has ready application to the surveying arts and in
particular in the quick and accurate laying out of new
markings in a previously survey region, at which one or more

30   base stations can be arranged.

    The system also has application in fleet management, for
example in creating record of distances travelled from base
locations and the spread of vehicular resources.

    Other applications include aircraft systems where the

35   present system can be used to supplement outer markers in

controlled air space. Also, crop dusting operators can accurately gauge the exact location for such operations thus preventing waste of material and possible damage to adjacent environments.

5   Furthermore, at an anticipated cost of A$500-$1000 (1992) per calculator, the system represents a cost effective alternative to optical systems without the expense of set-up times of such systems, and their inherent fragility. Accordingly, the present system offers an

10   inexpensive, and easy to use navigation system.

Furthermore, if the calculator 50,100 is used to record the pin and dogleg positions prior to the commencement of play, it is preferred that those positions be error corrected as they are taken, and not when entered into the

15   control unit 23 in the base station 20. This will prevent any change in the error affecting the accuracy of the fixed position data.

The foregoing describes only one embodiment of the present invention, and modifications, obvious to those

20   skilled in the art can be made thereto without departing from the scope of the present invention.

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APPENDIX 1

```
/
*********************************************************
****
        *              Pinranger Australia Pty. Ltd.        *
        *              Golf Distance Measuring system.      *
        *                                                   *
10      *                 Written by Tom Gunthorpe.         *
        *                       Copyright 1992              *
        *********************************************************
*******/
        PI    3.1415926535898
15      D2R   PI/180.0
        R2D   180.0/PI


        /* Pin location information (sample only) */
        /* Two dimensional array, (18 arrays of 2 elements) */
20
        /* Degrees in decimal format */
        pin_table[18][2] =
        {{-33.96050,151.22320},{-33.96035,151.22333},
         {-33.96058,151.22363},{-33.95997,151.22457},
25       {-33.96070,151.22275},{-33.96000,151.22333},
         {-33.96167,151.22500},{-33.96083,151.22417},
         {-33.96200,151.22583},{-33.96133,151.22667},
         {-33.95833,151.22500},{-33.96167,151.22167},
         {-33.96045,151.22353},{-33.95500,151.22167},
30       {-33.95583,151.22417},{-33.95333,151.21833},
         {-33.95167,151.23000},{-33.96050,151.22318}};


        /* Perform mathematical corrections and conversions */
        latlon()
35      {
```

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```
            lat1 = pin_table[pinnum][0];/* Stored in degrees
     */
            lon1 = pin_table[pinnum][1];
5           lat2 = latitude;                        /* Values
     from GPS   */
            lon2 = longitude;


        /* Calculate Latitude and Longitude differences in
10  meters.*/
        /* Longitude difference and corrections */
            a_axis = 6378137.0;              /* WGS84 default */
            londif = (lon1-lon2) * (((a_axis * 2.0 * PI)/360)
     * cos(latitude));
15
        /* Latitude difference */
            p_axis = 6357000.0;              /* The Polar radius
     = 6357km */
            latdif = (lat1-lat2) * ((p_axis * 2.0 * PI)/360);
20      }


        /* Calculate the Range between the two points */
        /* range = sqrt(((lat1-lat2)^2)+((lon1-lon2)^2)) */


25      range(float latdif, float londif)
        {
            rng = sqrt((latdif * latdif) + (londif * londif));
            printl("Range ");
            printd(rng);
                                                     /* 1 yard
30          return;
     = 0.9144 metres */
        }


        /* Calculate the Bearing from the standing location */
35      /* to the Pin, in degrees clockwise from true North. */
```

```
        bearing (float latdif, float londif)
        {
                if (latdif > 0.0 && londif > 0.0)
5                       brg = atan(latdif / londif);
                else if (latdif < 0.0 && londif > 0.0)
                        brg = atan((latdif / londif) * -1.0 ) ÷
(PI/2);
                else if (latdif < 0.0 && londif < 0.0)
10                      brg = atan(latdif / londif) + PI;
                else if (latdif > 0.0 && londif < 0.0)
                        brg = atan((latdif / londif) * -1.0 ) -
(PI/2) + PI;

15              bg = brg * R2D;              /* Convert radians
to degrees */
                printl("Bearing  ");
                printd(bg);
        return;
20      }
```

APPENDIX 2

First co-ordinates: lat   -33.96045
                          lon   151.22353

5

Second co-ordinatges: lat   -33.95853
                          lon   151.22789

abs delta lat = -33.96045 - -33.95985

10   = 0.00060 * 10000

                  = 60

abs delta lon = 151.22353 - 151.22412

                  = 0.00059 * 10000

15   = 59

Longitudinal convertion to metres.

$$Lg_{lt} = COS(lat) * Lg_{eq}$$

20

                  = COS(33.96) * 1.11319

                  = 0.8294277 * 1.11319

                  = 0.92331

25   delta lat(metres) = 60 * 1.10951

                          = 66.5706metres

delta long(metres) = 59 * 0.92331

                          = 54.47529metres

30

distance between two points =

$$SQR(((delta\ lat)^2)+((delta\ lon)^2)$$

$$= SQR(((66.5706)^2) + ((54.47529)^2))$$

35   = 86.02 metres

SUBSTITUTE SHEET

CLAIMS:

1.   A method for determining the distance between a
variable position and one or more of a plurality of fixed
positions, said method comprising the steps of obtaining
5   first satellite position information of one of said fixed
positions and supplying said first information to a user for
use at said variable position, said user obtaining second
satellite position information of said variable position,
and subsequently calculating the distance between said
10   variable position and said fixed position using said first
position information and said second position information.

2.   A method as claimed in claim 2, wherein t e step
of supplying said first information comprises radio
frequency transmission for complementary reception of said
15   first information at said variable position.

3.   A method as claimed in claim 1, wherein the step
of supplying said first information comprises a direct
transfer of said information to said user prior to the use
thereof at said variable position.

20   4.   A method as claimed in claim 1, 2 or 3, comprising
the further step of obtaining a third satellite position
information of a reference location and comparing same with
survey position information of said reference location to
determine a satellite position information error, said error
25   being supplied to said user to permit correction of errors
in said first and second position information, prior to
calculating said distance.

5.   A method as claimed in claim 4 when dependent on
claim 2, wherein said error is periodically redetermined and
30   retransmitted to said variable position thereby permitting
real-time correction of at least said second position
information.

6.   A distance measuring system comprising a base
station having a control means and a data transmitter means,
35   said control means being configurable with first satellite

position information obtained from a (first) portable
satellite position receiver, of one or more fixed positions,
said first position information being communicable by said
data transmitter means to one or more portable distance
5   calculators, each said distance calculator comprising a
(second) satellite position information receiver, a data
receiver means adapted to receive data from said data
transmitter means, and a processor means, said processor
means accepting said first satellite position information of
10 one of said fixed positions selected by a user of said
calculator and actual position information provided by said
second satellite position receiver, and subsequently
calculating the distance therebetween and presenting said
distance for consideration by said user.

15   7.   A system as claimed in claim 6, wherein said data
transmitter means comprises a radio transmitter and said
data receiver means comprises a complementary radio
receiver.

        8.   A system as claimed in claim 6, wherein said data
20 transmitter means comprises a hardware interconnection port
connectable to a complementary port in said data receiver
means thereby permitting direct communication of said first
position information therebetween.

        9.   A system as claimed in claim 6, further comprising
25 a third satellite position information receiver arranged at
a reference location and configured to periodically provide
satellite position information of said reference location to
said control means whereby said control means compares a
pre-determined survey position of said reference location
30 with said satellite position information of said reference
location to determine a satellite position information
differential error, said error being supplied to each one of
said calculators for correction of satellite position
information used by said calculators.

35

10.   A system as claimed in claim 9, wherein said data transmitter means comprises a radio transmitter and said data receiver means comprises a complementary radio receiver for radio frequency communication of said first satellite

5   position information and said differential error.

11.   A system as claimed in claim 9, wherein said data transmitter means comprises a radio transmitter for radio frequency communication of said differential error, and a hardware interconnection port for physical communication of

10   said first satellite position information to said calculator, said data receiver means comprising a complementary radio receiver for receiving said differential error and a complementary port for receiving said first satellite position information.

15   12.   A system as claimed in claim 9, 10 or 11, wherein said third satellite position information receiver is arranged at said base station and a receive antenna of same is arranged at said reference location about said base station.

20   13.   A system as claimed in any one of claims 6 to 12, wherein said satellite position information is obtained from one or more satellites of a satellite positioning system and said distance calculations include corrections for longitude, latitude and altitude data received from said

25   satellite(s).

14.   A system as claimed in claim 13 when dependent on claim 9, wherein said third satellite position information receiver can simultaneously receive satellite position information from a plurality of satellites, said control

30   means thereby determining a like plurality of said differential errors and forwards same to said calculator for error correction prior to determination of said variable position.

15.   A system as claimed in claim 11, wherein said

35   radio transmitter means and said radio receiver means are

adapted for communication of said first satellite position information with said differential error.

16. A system as claimed in claim 15, wherein said portable calculator comprises a microcontroller means and a
5   memory means arranged for storage of said satellite position information, a keypad means operable by said user to select any of said fixed positions and for enabling said actual position information received from said second satellite position information receiver to said microcontroller means
10   for retention in said memory means, said complementary port connecting to said microcontroller means, and a display means interconnected to said microcontroller means for displaying said distance to said user.

17. A system as claimed in claim 16, wherein said
15   display means comprises a 2-dimensional pixel array and said memory means can be input with map data including said fixed positions and encompassing areas at which said actual position can be located to thereby enable visual display to said user of the relative relationship between said actual
20   position and any one or more of said fixed positions.

18. A system as claimed in claim 17, wherein said map data is provided to said calculator via said complementary port or preprogrammed in a portable memory device.

19. A system as claimed in claim 17 or 18, wherein
25   said fixed positions relate to selected positions about a golf course and said actual position is a position of a golf ball on said course, whereby said calculator enables said user to determine the distance between said ball and one of said selected position, so as to thereby provide an
30   indication to a golf player of the particular golf club that should be selected for the next stroke of the ball to approach said one selected position.

20. A system as claimed in claim 19, wherein said fixed positions are pin hole and dog-leg positions about said golf course, which are entered into said control means
35

for supply to said calculators and are updated
contemporaneously with variations in said fixed positions.

21. A system as claimed in any one of claims 9 to 20,
wherein said distance can be determined to an accuracy of

5   ± 2-5 metres.

22. A system as claimed in any one of claims 9 to 21
wherein said calculator further determines a bearing to be
travelled from said variable position to said fixed
position.

10   23. A system as claimed in claim 22 when dependent on
claim 19 or 20 wherein said calculator determine. for the
next stroke, a correction bearing based on said variiable
position resulting from the previous stroke and the previous
variable position.

15   24. A portable distance calculator for use with the
invention as claimed in any one of the preceding claims.

AMENDED CLAIMS
[received by the International Bureau on 13 April 1993 (13.04.93);
original claims 1 - 24 replaced by amended claims 1 - 16 (3 pages)]

1.   A transportable distance calculator comprising:

a (first) satellite position information receiver for
determining satellite position information of said

5   calculator;

memory means for retaining fixed position information
of one or more fixed positions;

receiver means for real-time reception of satellite
positional error information; and

10   processor means for firstly using said error
information to correct said calculator satellite position
information in real-time and to thereby determine and
display a distance between said calculator and a selected
one of said fixed positions.

15   2.   A distance measuring system comprising:

at least one transportable distance calculator as
claimed in claim 1; and

a base station comprising:

a second satellite position information receiver for

20   continuously determining satellite position information of
said base station;

control means for comparing said base station satellite
information with a predetermined reference position of said
base station to determine said positional error information

25   in real-time; and

transmitter means for transmitting said error
information for reception by said receiver means.

3.   A system as claimed in claim 2, wherein said
control means comprises a store for retaining said fixed

30   position information and a communication means for
transferring said fixed position information to said
calculators.

4.   A system as claimed in claim 3, wherein said
communication means comprises a hardware interconnection

35   port connectable to a complementary port in one of said

calculators for direct transfer of said fixed position information.

5. A system as claimed in claim 3, wherein said communication means interconnects said store with said transmitter means for transmission of said fixed position information to said calculators.

6. A system as claimed in claim 2, wherein said fixed position information comprises survey data one or more of said fixed positions.

7. A system as claimed in claim 2, wherein said fixed position information is determined by operating one of said calculators at one or more said fixed positions, and simultaneously error correcting said fixed positions with said positional error information prior to storing said fixed positions in said memory means from which it can be transferred to said control means.

8. A system as claimed in claim 7, wherein said fixed positions are transferred by displaying said fixed position information on said calculator and manually entering same into said control means.

9. A system as claimed in claim 2, wherein said transmitter means and said receiver means utilize radio frequency communication from said base station to said calculator.

10. A system as claimed in claim 2, wherein said second satellite position information receiver can simultaneously receive satellite position information from a plurality of satellites from which said control means can thereby determine a like plurality of positional error information which is thereby transferred to said calculator for correcting said calculator satellite position information obtained from the same satellite.

11. A system as claimed in claim 2, wherein said fixed positions are positions about a golf course and said calculator is operable at a golf ball position on said golf

course whereby the lineal distance between the golf ball and a selected one of said positions is determined and substantially instantaneously displayed on a display means to a user of said calculator.

5   12. A system as claimed in claim 11, wherein said display means comprises a 2-dimensional pixel array and said memory means can be input with map data including said fixed positions and encompassing areas at which said golf ball can be positioned to thereby enable visual display to the user
10   the relative relationship between the golf ball position and any one or more of said fixed positions.

13. A system as claimed in claim 11, wherein having determined said distance, said calculator indicates to the user a particular golf club that should be selected for a
15   next stroke of the golf ball to approach a selected one of said fixed positions.

14. A system as claimed in claim 1, wherein said calculator further determines and displays a bearing from said calculator to said selected one fixed position.

20   15. A system as claimed in claim 11, wherein said fixed positions are pin hole and dog-leg positions about said golf course.

16. A system as claimed in claim 1, wherein said calculator is configured in a unitary hand-held portable
25   form.
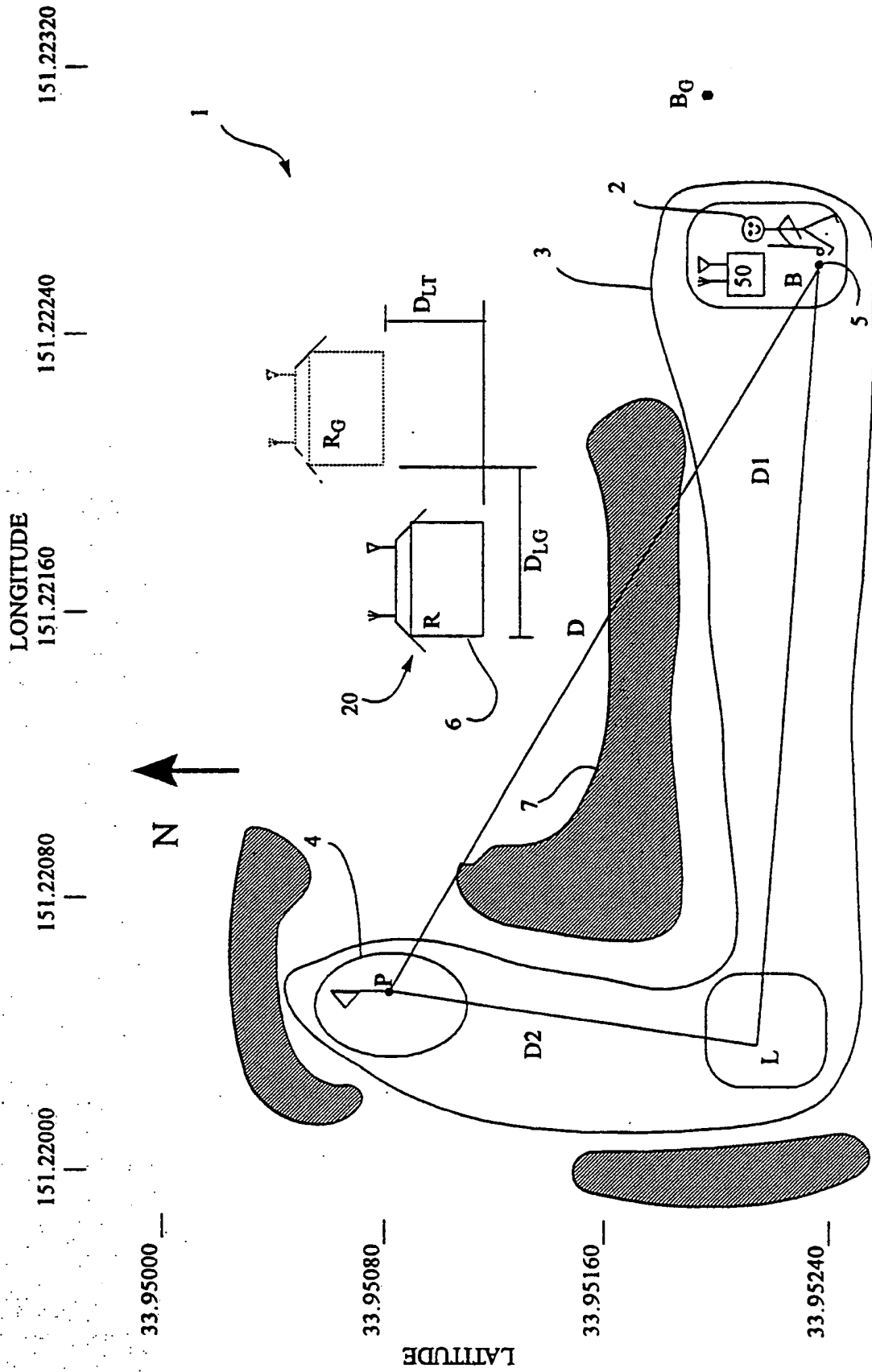
30

35

FIG. 1

FIG. 2

FIG. 7

52 → DATA Rx

GPS Rx ← 51

50

53 → INPUT BUFFER

54 → PROCESSOR

55 → KEYPAD

56 → DISPLAY

MEMORY ← 57

Product Code ← 58

PIC

59

Pin 1 position

Pin 2 dogleg

Pin 2 position　← 61

Pin 18 position

GPS Error ← 62

GPS Position ← 63

FIG. 3

FIG. 4

FIG. 5

FIG. 6
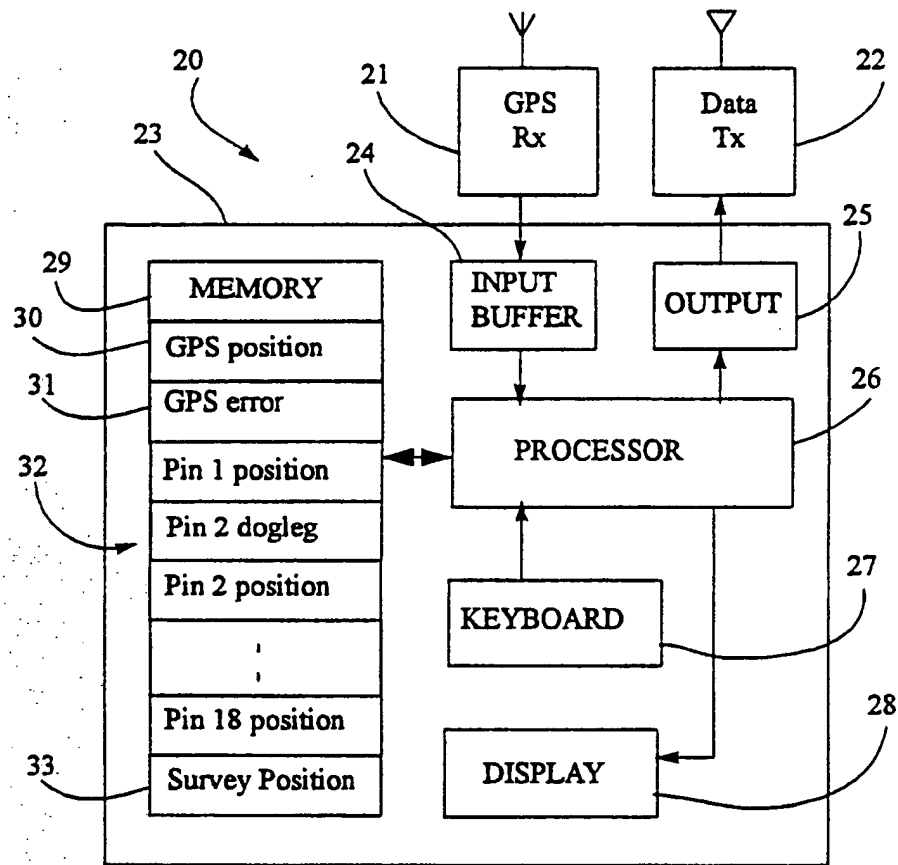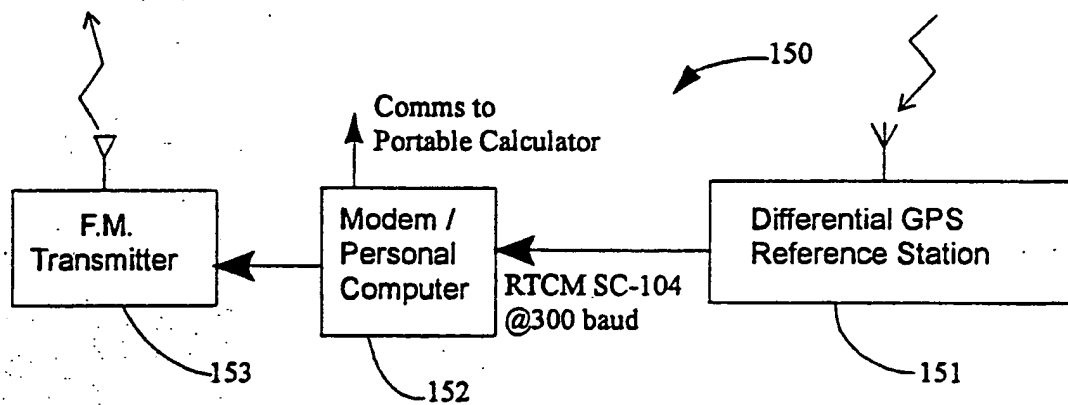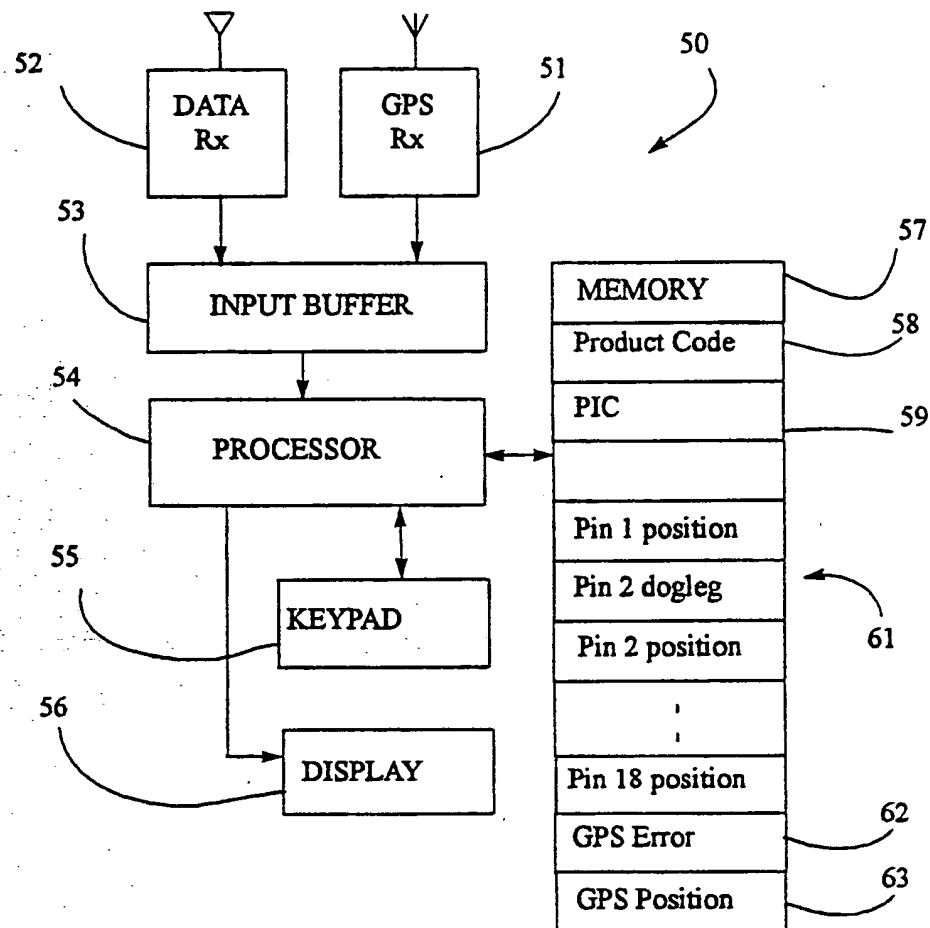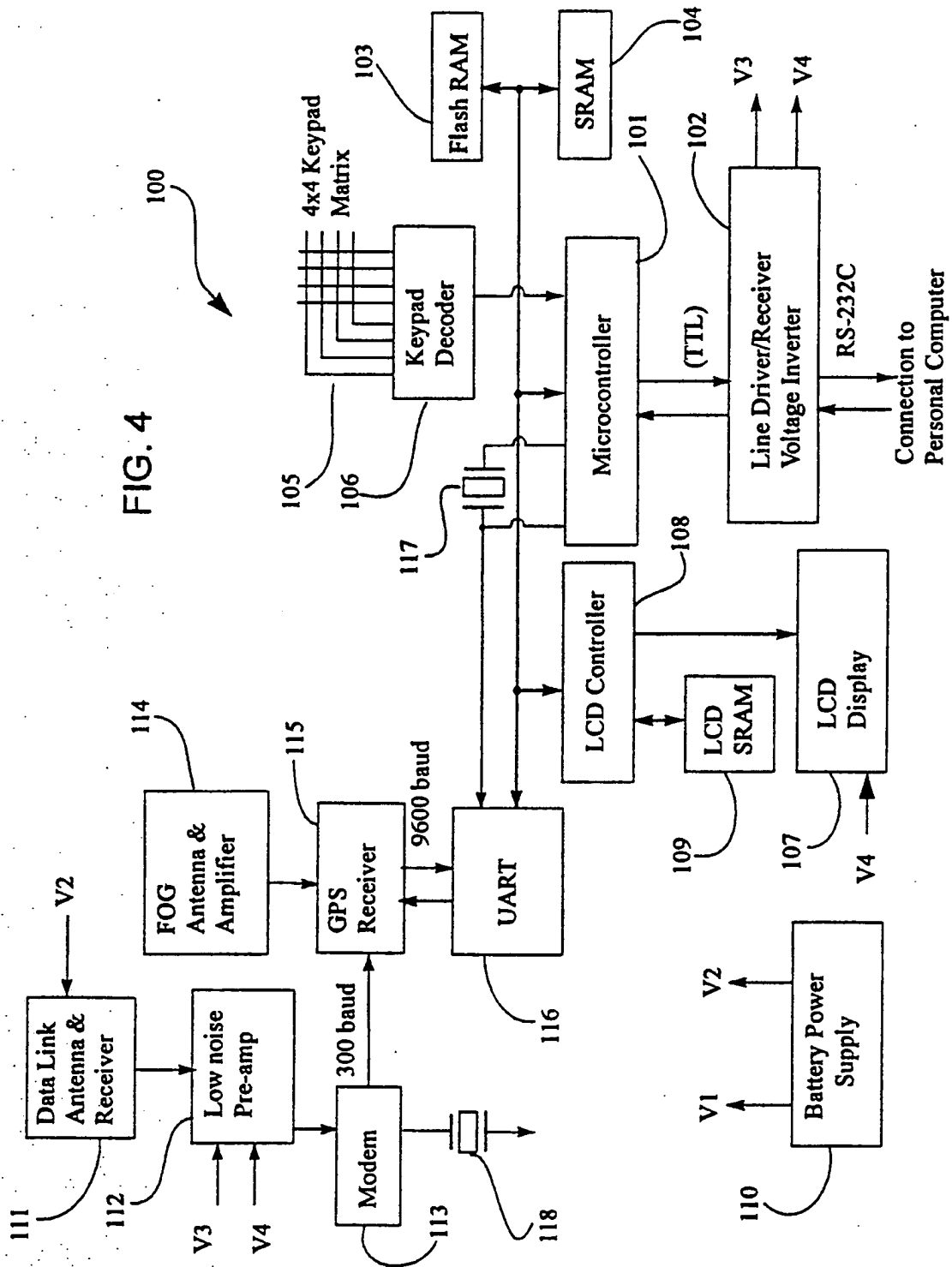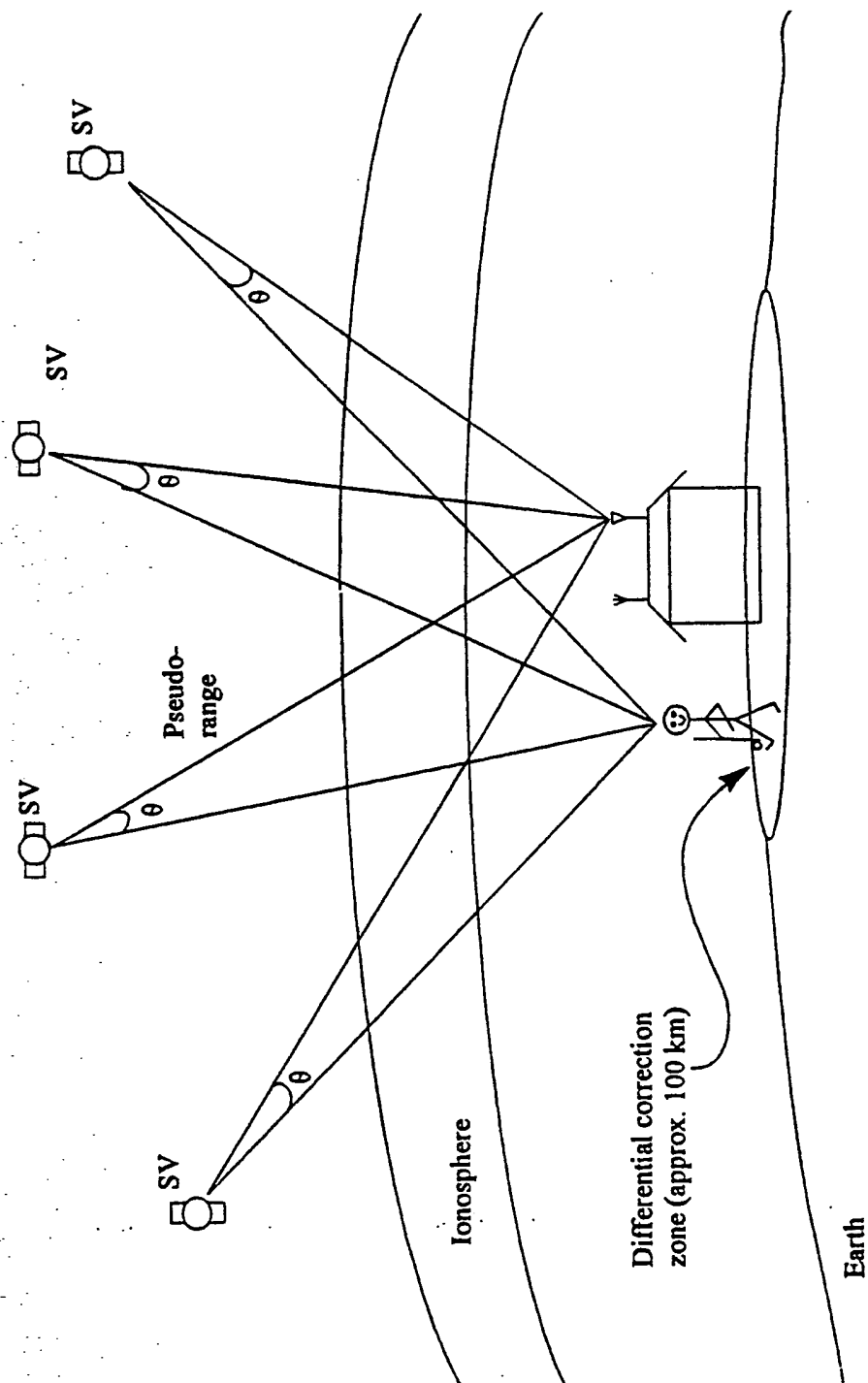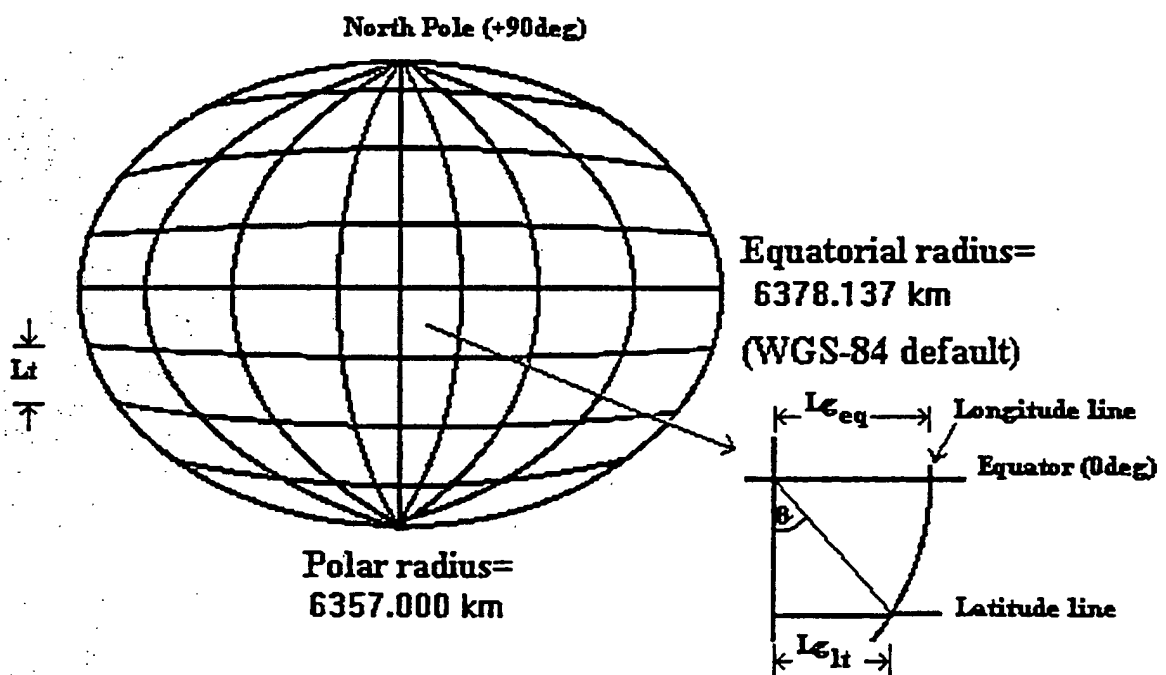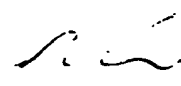
A.	CLASSIFICATION OF SUBJECT MATTER

Int. Cl.5   G01S 5/10, 11/02

.:ccording to International Patent Classification (IPC) or to both national classification and IPC

	FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : G01S 5/10, 5/14, 11/00, 11/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)

C.	DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
P,X	GB,A, 2249202 (OSAMU) 29 April 1992 (29.04.92) Abstract. Claims.	1-23
X	GB,A, 2213339 (THE SECRETARY OF STATE FOR DEFENCE) 9 August 1989 (09.08.89) Abstract. Figure.	1-23
X	US,A, 4973970 (REESER) 27 November 1990 (27.11.90) Abstract, Column 5 lines 3/17	1-23

X	Further documents are listed in the continuation of Box C.	X	See patent family annex.

*	Special categories of cited documents :	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		
		"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 February 1993 (12.02.93)	16 FEB 1993 (16.02.93)

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA	R. CHIA
Facsimile No. 06 2853929	Telephone No. (06) 2832185

Form PCT/ISA/210 (continuation of first sheet (2)) (July 1992) copjne

C(Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
X	US,A, 4894655 (JOGUET et al) 16 January 1990 (16.01.90) Abstract. Figures.	1-23
X	US,A, 4812991 (HATCH) 14 March 1989 (14.03.89) Abstract. Figure 1, Claim 1.	1-23
X	EP,A, 444738 (PHILIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LIMITED) 4 September 1991 (04.09.91) Abstract. Figures.	1-23
P,X	AU,A, 14997/92 (NAVSYS CORPORATION) 12 November 1992 (12.11.92) Abstract. Figure 1.	1-23
X	AU,A, 63995/90 (AUSPACE LIMITED) 18 April 1991 (18.04.91) Abstract. Figure 1. Page 5 line 20/Page 6 line 6.	1-23

| Box I | Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet) |

This international search report has not established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claim Nos.: 24
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

The invention referred to is indeterminate and it is not drafted in accordance with Rule 6.3.

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

| Box II | Observations where unity of invention is lacking (Continuation of item 2 of first sheet) |

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically

claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
GB	2249202	NONE					
GB	2213339	NONE					
US	4973970	CA	2016309	EP	408179		
US	4894655	CA	1297972	EP	283353	FR	2611399
US	4812991	AU	74356/87	CA	1268239	EP	264440
		IL	82387	WO	8706713		
EP	444738	GB	2241623	US	5119102		
AU	14997/92	CA	2066831	EP	512789		
AU	63995/90	NONE					

END OF ANNEX